National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mars Exploration Program Analysis Group

Fuk Li

September 2010

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California Institute of Technology
Pasadena, California

Possible MEP Portfolio

JPL

NASA-ESA Joint Mars Initiative

Operational 2001-2007	2009	2011	2013	2016	2018	2020 & Beyond
Odyssey, MRO, Mars Express Collaboration			MAVEN Aeronomy Orbiter	ESA—NASA ExoMars Trace Gas Orbiter	The Era of Mars Sample Return begins	
MER, Phoenix (completed)		Mars Science Laboratory			NASA—ESA Rovers (Astrobiology/ Sample Return Cache)	

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Highlights of Mars Operating Missions

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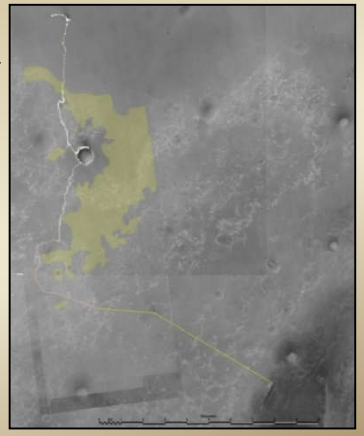
Mars Exploration Directorate

MER



Opportunity to Endeavor

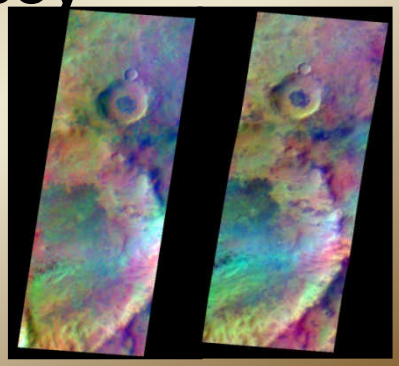
Spirit Front and Rear Rover Embedded

2 MER rovers still operational after 6 years on Mars surface

- Opportunity marching towards Endeavor crater
- Spirit embedded in 'Troy'
- Spirit winter survival

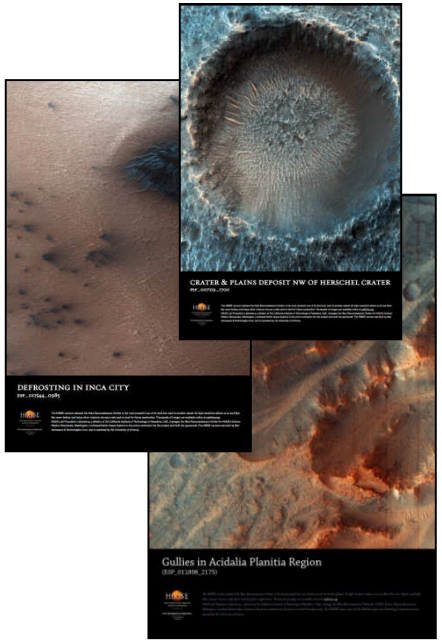
Odyssey

Sept. 2003 Local true solar time = 4:32 p.m.



May 2009 Local true solar time = 3:21 p.m.

- Completed Orbit change to local solar time of ~3:45 pm: allows significant improvements in the SNR for THEMIS IR mapping



MRO has completed mission scientific Level I requirements

- Continues to acquire science data with all its instruments
- Project acquired over 100 Tbits
  - Has acquired 3X more data than all deep space missions beyond the moon combined
- Continues to map a wide variety of Martian terrain suitable for future landing missions

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MSL Mission Overview

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Mars Explor… …te

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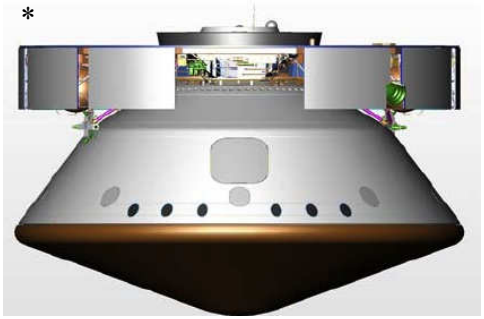
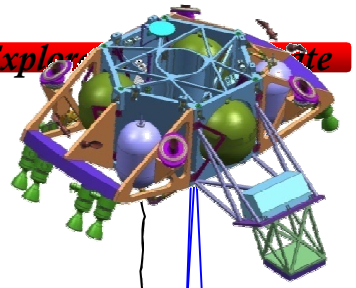


CRUISE/APPROACH

- 9 month cruise
- Spinning cruise stage
- Arrive N. hemisphere summer

ENTRY, DESCENT, LANDING

- Guided entry and controlled, powered “sky crane” descent
- 20 × 25-km landing ellipse
- Discovery responsive for landing sites ±30º latitude, <0 km elevation
- ~1000-kg landed mass



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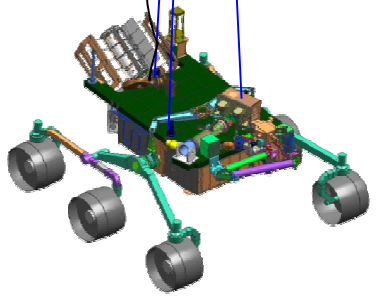
SURFACE MISSION

- Prime mission is one Mars year
- Latitude-independent and long-lived power source
- 20-km range
- 85 kg of science payload
- Acquire and analyze samples of rock or soil
- Large rover, high clearance; greater mobility than MPF, MER



LAUNCH

- Nov. 2011
- Atlas V (541)

* Artist’s Renderings

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MSL - Payload

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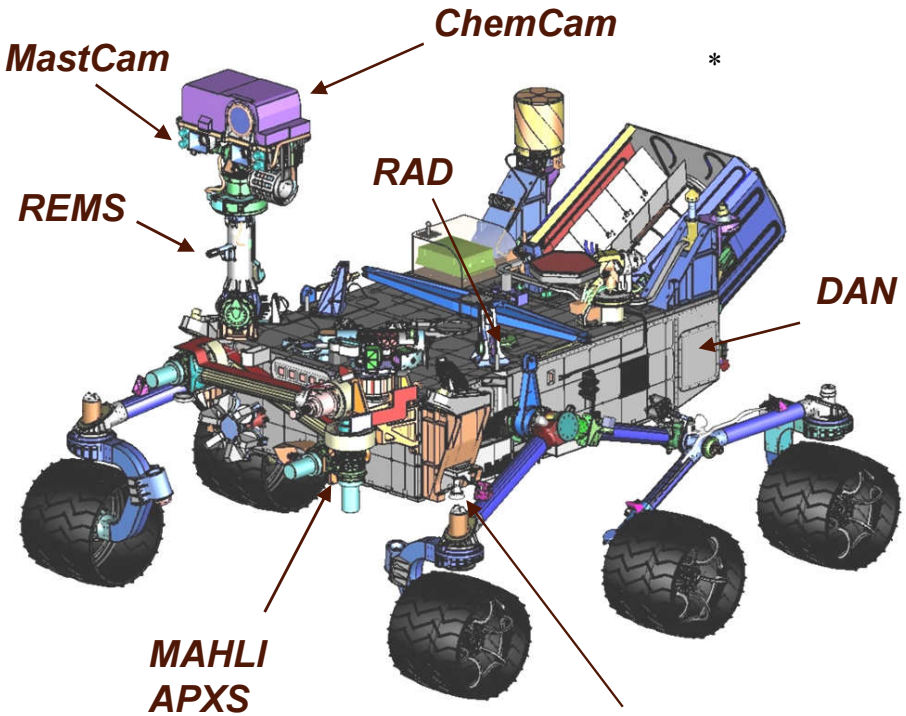


* Artist's Rendering

Wheel Base:	**2.2 m**
Height of Deck:	**1.1 m**
Height of Mast:	**2.2 m**

REMOTE SENSING

- **Mastcam** (M. Malin, MSSS) – Narrow and wide angle color imaging, atmospheric opacity

  ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging
  - Mast Unit
  - Body Unit

CONTACT INSTRUMENTS (ARM)

- **MAHLI** (K. Edgett, MSSS) - Microscopic imaging
- **APXS** (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

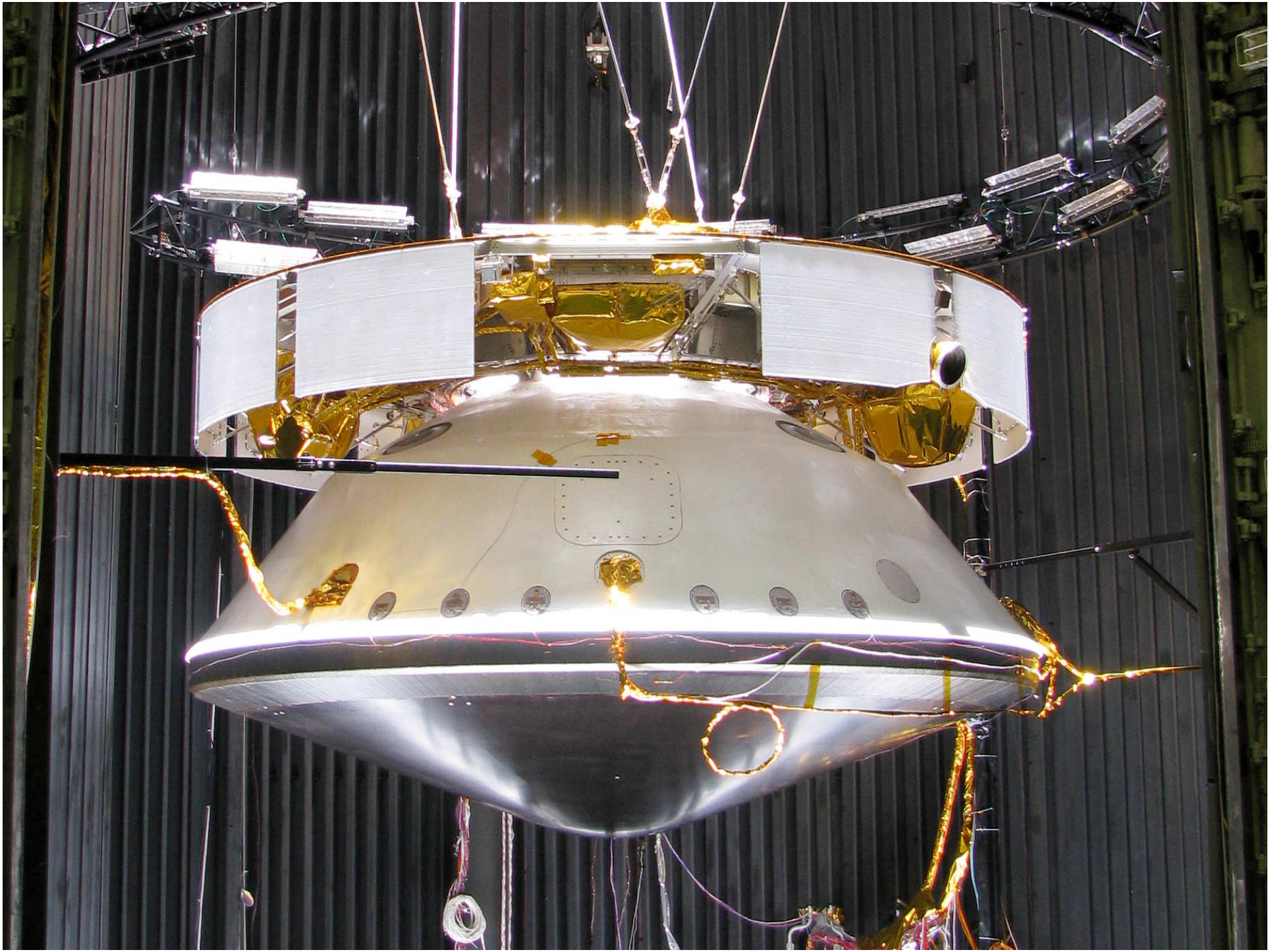
SAM (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics (Dec. '10)

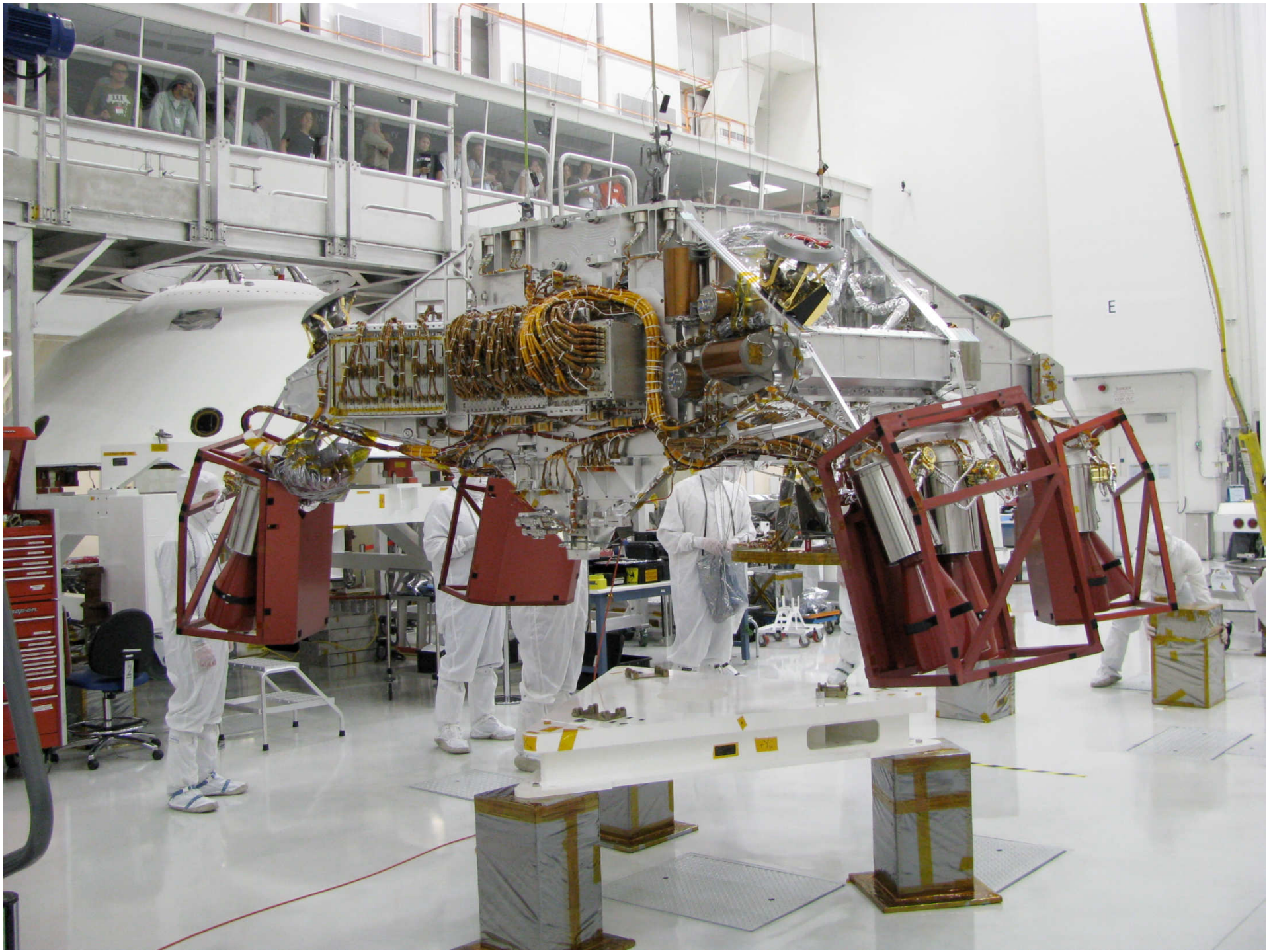
- **CheMin** (D. Blake, ARC) - Mineralogy

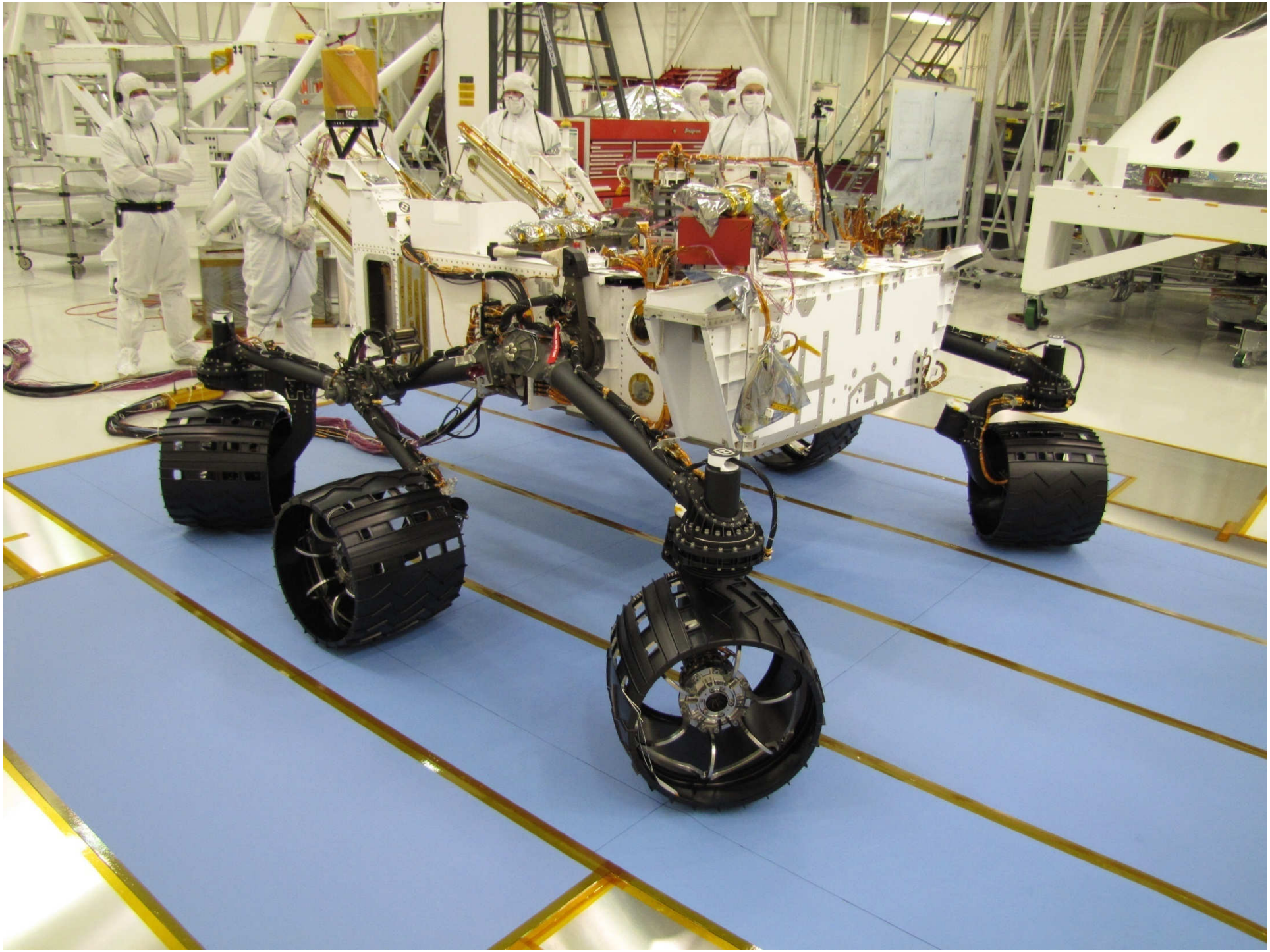
ENVIRONMENTAL CHARACTERIZATION

- **MARDI** (M. Malin, MSSS) - Descent imagery
- **REMS** (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV
- **RAD** (D. Hassler, SwRI) - High-energy radiation
- **DAN** (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

Delivered Integrated







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MSL Moving In Spacecraft Assembly Facility

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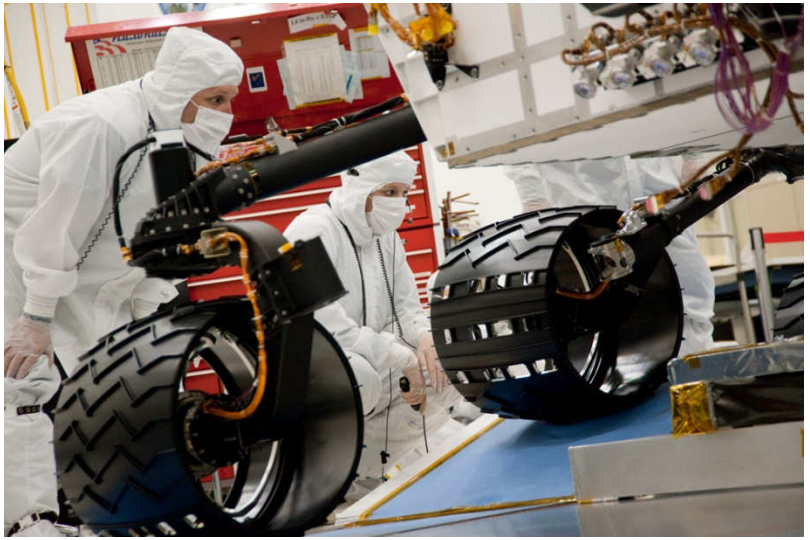

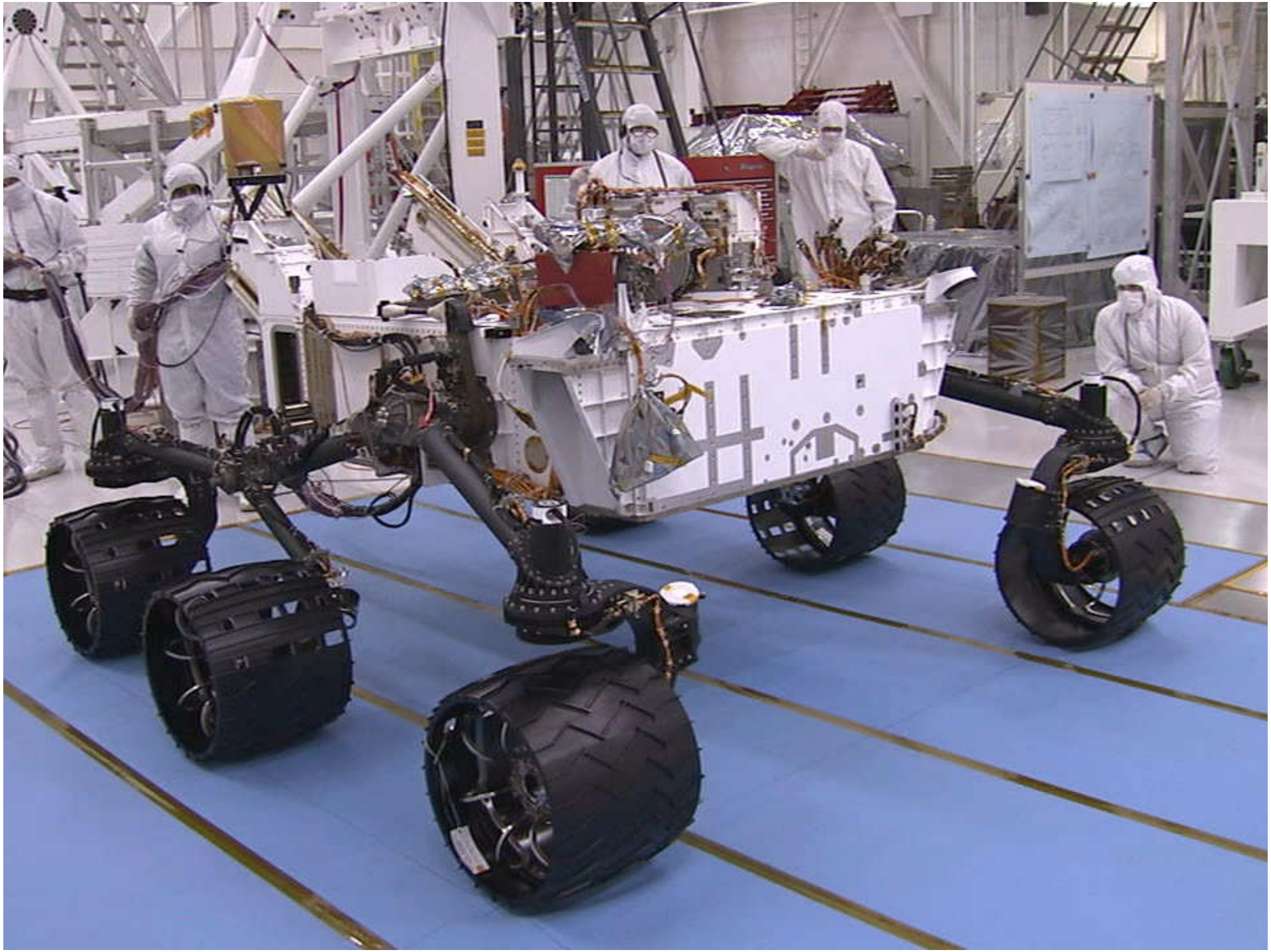

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MAVEN - Mission Overview

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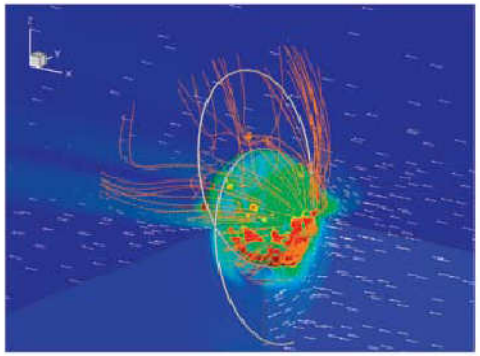

Mission Objectives

- Determine the role that loss of volatiles from the Mars atmosphere to space has played through time, exploring the histories of Mars' atmosphere and climate, liquid water, and planetary habitability
- Determine the current state of the upper atmosphere, ionosphere, and interactions with solar wind
- Determine the current rates of escape of neutrals and ions to space and the processes controlling them
- Determine the ratios of stable isotopes that will tell Mars' history of loss through time

Organizations

- LASP – PI and science team; E/PO; science operations; IUVS and LPW instruments
- GSFC – project management; mission systems engineering; safety and mission assurance; project scientist; NGIMS and MAG instruments
- JPL – Navigation; DSN; Mars Program Office
- SSL – Deputy PI; Particles and Fields Package management; STATIC, SEP, SWIA, and SWEA instruments; LPW probes and booms (CESR provides the sensor for SWEA)
- LM – spacecraft; assembly, test and launch operations; mission operations

Launch

- On an EELV from KSC between 11/18/13 and 12/7/13
- Mars Orbit Insertion on 9/16/14 (for 11/18/13 launch)

Website

http://lasp.colorado.edu/maven/

Mission Approach

- Obtain detailed measurements of the upper atmosphere, ionosphere, planetary corona, solar wind, solar EUV and SEPs over a 1-year period, to define the interactions between the Sun and Mars
- Operate 8 instruments for new science results:
  - Particles and Fields Package (6 instruments):
    - SWEA - Solar Wind Electron Analyzer
    - SWIA - Solar Wind Ion Analyzer
    - STATIC - Suprathermal and Thermal Ion Composition
    - SEP - Solar Energetic Particle
    - LPW - Langmuir Probe and Waves - EUV
    - MAG - Magnetometer
  - IUVS - Imaging Ultraviolet Spectrometer
  - NGIMS - Neutral Gas and Ion Mass Spectrometer
- Fly 75° -inclination, 4.5-hour-period, 150-km-periapsis-altitude science orbit
- Perform five 5-day "deep dip" campaigns to altitudes near 125 km during the 1-year mission

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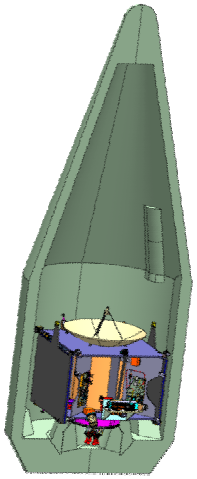
MAVEN - Mission Architecture

Mars Exploration Directorate

20-Day Launch Window



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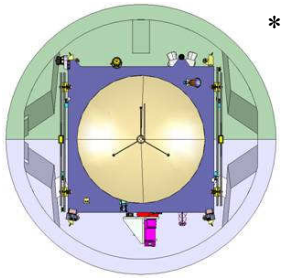
18 Nov 2013 (Open)
7 Dec 2013 (Close)

LV: TBD (EELV)



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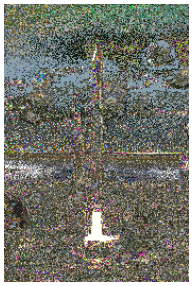
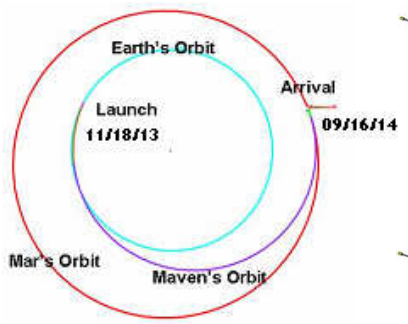


Ten Month Ballistic Cruise to Mars

Type-II Trajectory



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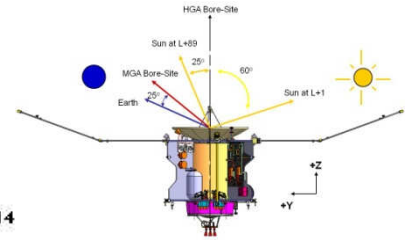
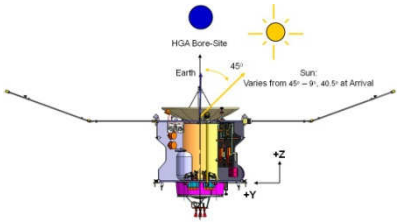
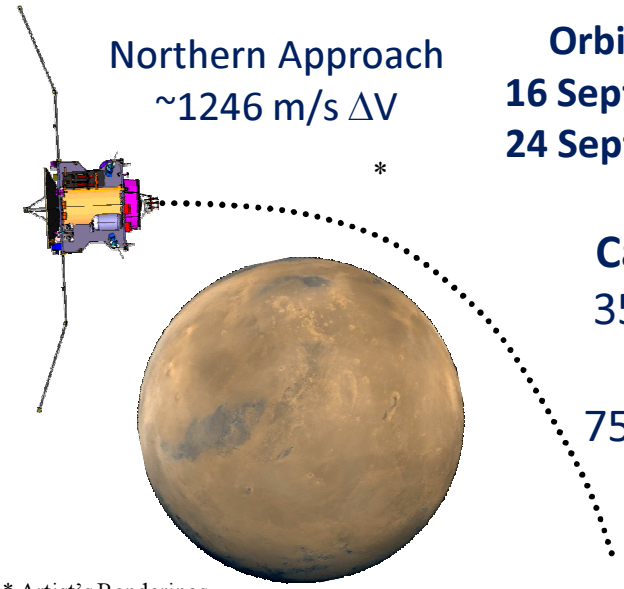


Early Cruise



Late Cruise



Northern Approach
~1246 m/s ΔV

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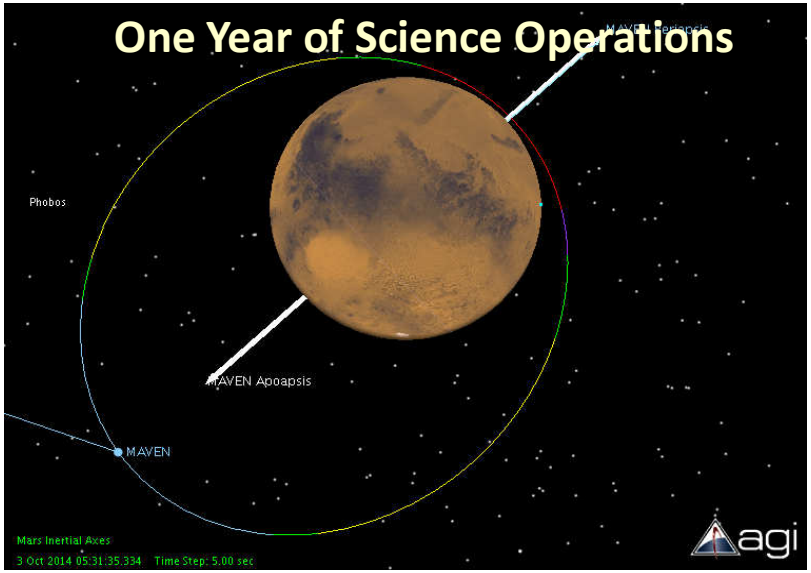
Orbit Insertion:
16 Sept 2014 (Open)
24 Sept 2014 (Close)

Capture Orbit:
35 hour period
550 km P2
75° inclination



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MAVEN - Status and Plans

- Conducted Mission PDR July 12-15, 2010
  - Culmination of 60+ peer reviews and element PDRs
  - Standing Review Board reported that the project passed the review
  - Science objectives from time of selection are on track to be accomplished within proposed budget
- Ready for KDP-C / confirmation review
- Phase C to start on November 1, 2010

Confirmation Review:
October 4, 2010

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Proposed 2016 ExoMars/Trace Gas Orbiter

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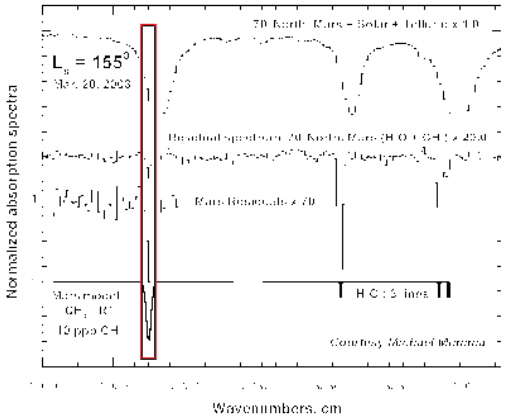
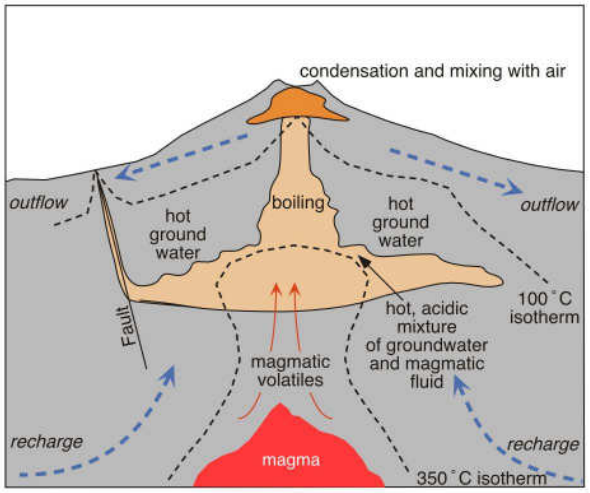
Instrument	PI	Institution
Mars Atmosphere Trace Molecule Occultation Spectrometer (MATMOS)	Paul Wennberg	California Institute of Technology
High Resolution Solar Occultation and Nadir Spectrometer (SOIR-NOMAD)	Ann C. Vandaele	Belgian Institute for Space Aeronomy
ExoMars Climate Sounder (EMCS)	John Tim Schofield	Jet Propulsion Laboratory
High Resolution Color Stereo Imager (HiSCI)	Alfred McEwen	University of Arizona
Mars Atmosphere Global Imaging Experiment (MAGIE)	Bruce Cantor	Malin Space Science

Detection of Methane on Mars
Mumma et al., 2010, *Science*





Abiotic?

Biotic?

Evidence of an active subsurface?

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Current 2018 Mars Mission Concept Architecture

Land NASA rover and ExoMars rover together attached to a landing platform

- NASA rover and ExoMars rover perform *in situ* science exploration: assessing potential joint experiments
- NASA rover would cache scientifically selected samples for potential future return

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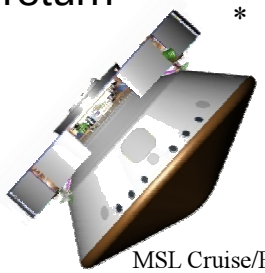

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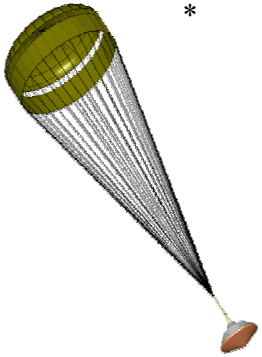

MSL Cruise/EDL and Skycrane system lands Rovers on platform

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Sample Canisters On Mars Surface

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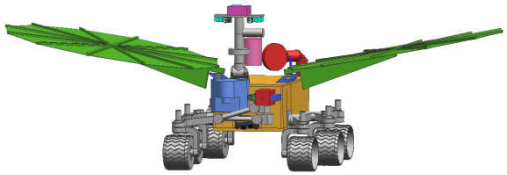

Study Concept Includes:

- Landing platform (pallet), 'proof-of-concept'
- Scaling of MSL aeroshell diameter (from 4.5 m to 4.7 m) to accommodate 2 rovers
- Descent stage architecture/design based on MSL
- Land in ~10 km radius landing ellipse, up to -1 km altitude, within +25 to -15 degrees latitude.

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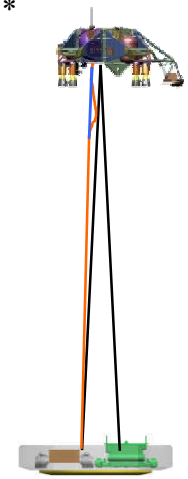

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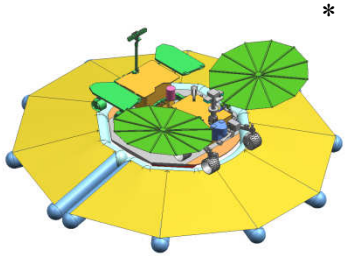

Rovers post-landing w/ example egress aids

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